Missouri Water Resources Research Center
Annual Technical Report
FY 2010

Introduction

Water Resources Research Center Annual Technical Report FY 2010-2011

WATER PROBLEMS AND ISSUES OF MISSOURI

The water problems and issues in the State of Missouri can be separated into three general areas: 1) water quality, 2) water quantity, and 3) water policy. Each of Missouri's specific problems usually requires knowledge in these three areas.

Water Quality: News media attention to the occurrence of pesticides and nutrients in the Midwest has raised a serious public concern over the quality of Missouri's drinking water and how it can be protected. With the large agricultural activity in the state, non-point source pollution is of major interest. Because of several hazardous waste super-fund sites, hazardous waste is still of a concern to the public. Areas of research for the past ten years have included (but are not limited to): erosion, non-point pollution reclamation of strip mine areas, hazardous waste disposal, acid precipitation, anthropogenic effects on aquatic ecosystems and wetlands,Developing Guidelines for Polyacrylamide Use for Erosion and Runoff Reduction, and Visible Light-activated Titanium Dioxide-based Photocatalysts: Synthesis and Potential Environmental Applications.

Water Quantity: Missouri has a history of either inadequate amounts of rainfall, or spring floods. Because of the 1987-89 drought years and the floods of 1993 and 1995, water quantity has become a major topic of concern. Research is needed to better understand droughts and flood conditions.

Water Policy: Policies and program need to be formulated that will ensure continued availability of water, as new demands are placed on Missouri s water. The social and economic costs may no longer be held at acceptable levels if water becomes a major issue in cities and rural areas. Past droughts and possible lowering of the Missouri River have raised serious questions over states rights to water and priority uses. Research areas in this program have included drought planning, legal aspects, perception and values, economic analysis, recreation, land/water use policy and legislation, and long-term effects of policy decisions.

Research Program Introduction

The Missouri Water Resources Research Center's objectives are: 1) to establish active research programs to aid in understanding and solving Missouri's and the Nation's water problems, 2) to provide education opportunities in research for students with an interest in water resources and related fields, and 3) to be actively dedicated to the dissemination of information through all aspects of the media.

The Center mobilizes the best faculty expertise in the state to examine specific water resources problems. The Center and its advisory committee are familiar with Missouri's research needs and current projects. They help researchers avoid duplicate efforts, while serving as a link between the research community and potential users of research results such as industries, planning commissions, and state agencies.

Missouri's economy revolves around its water resources; therefore, the Center works closely with the state in addressing their problems by providing research data, which are necessary in order to solve present and future water problems.

The administrative activities necessary to support this program include:

Solicitation of Missouri proposals under 104b; Coordination with the advisory committee in the review and selection of the proposals; Preparation and submission of Proposal to USGS; Continuous review of funded projects including visits to funded P.I.s to evaluate progress; Prepare Annual Report to USGS; Review of final reports and dissemination of results to the public;Preparation of necessary national reviews; Review of 104G proposals

Developing Guidelines for Polyacrylamide Use for Erosion and Runoff Reduction

Basic Information

Title:	Developing Guidelines for Polyacrylamide Use for Erosion and Runoff Reduction
Project Number:	2009MO100B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	9
Research Category:	Water Quality
Focus Category:	Surface Water, Nutrients, Water Quality
Descriptors:	None
Principal Investigators:	Clark Gantzer, Allen L. Thompson

Publications

1. Lee, S.S., C.J. Gantzer, A.L. Thompson, S.H. Anderson. 2010. Polyacrylamide and gypsum amendments for erosion and runoff control on two dissimilar soils. J. Soil Water Conserv. 65:in press.
2. . Lee, S.S., C.J. Gantzer, A.L. Thompson, S.H. Anderson. 2010. Polyacrylamide and gypsum amendments for erosion and runoff control on two dissimilar soils. J. Soil Water Conserv. 65(4):233-242.
3. Lee, S.S., C.J. Gantzer, S.H. Anderson, and. A.L. Thompson. 2010. Saturated hydraulic conductivity of surface seals estimated from computed-tomography-measured porosity 2010 SWCS Annual Conference July 18-21, 2010. St. Louis, MO. (non-refereed- abstract).
4. Lee, S.S., C.J. Gantzer, A.L. Thompson, and S.H. Anderson. 2011. Polyacrylamide efficacy for reducing soil erosion and runoff as influenced by slope. J. Soil Water Conserv. 66 (3): 172-177.

Annual Progress Report - Missouri Water Resources Research Center

Title: Developing Guidelines for Polyacrylamide Use for Erosion and Runoff Reduction.

Name: C.J. Gantzer, and A.L. Thompson

Nature, Scope and Objectives of Research:

Work was to evaluate soil erodibility as influenced by Polyacrylamide **(**PAM) and Ca^{++} was done using a single drop splash device (Gantzer et al., 1985)). Eighteen different soils were collected for study to determine the binding effect of polyacrylamide (PAM; or PAM with Ca^{++}) on soil to reduce soil erodibility as influenced by the clay-sized particles, clay type, and related soil properties.

The goal of this study is to quantify effectiveness of two rates of PAM application for reducing erosion on disturbed soil for different soil textures and mineralogy. Research on this topic will provide the basis for a model to recommend beneficial PAM application on various soils, mineralogy, and slopes. Results will contribute to improving conservation guidelines for control of soil erosion and runoff. The uniqueness of this study is the quantification of PAM effectiveness under the variable texture, pH, mineralogy, and slope conditions. We know of no other work that has evaluated these factors in combination to produce results that can be used to develop specific guidelines for PAM use under a variety of conditions. Packed soil cores of soils treated with two levels of PAM, two levels of Ca++ will be tested for soil erodibility. Prediction equations relating the effect of PAM for reducing soil erodibility on these soils vs. the amount of PAM applied to these soils will be developed as a guideline for users to aid in selecting the most economical and effective amount of PAM. Results of this testing will be presented at the Annual International Soil and Water Conservation Society Meetings in July 2011. This work will be submitted for peer-reviewed publication.

Progress:

Testing for research of erosion reduction due to application of PAM and Ca^{++} was done on seventeen soil samples and four pure mineral samples. The other variable in the experiment was the type of solution applied to the surface. There were six different solution treatments for each soil series as well as three replicates of each treatment. Each soil sample prepared would be

tested three times. This produced nine samples for each treatment and fifty-four samples for each soils series. With the pure mineral samples we used the same solution treatments, but only had five replicates. Each of the replicates was only tested once, which means that we had thirty samples for the pure minerals.

Seventeen soil series were collected from field sites throughout Missouri in order to use the sampling data to make predictions about the effects of the various treatments on any soil found in the state. A majority of the soils collected were subsoil. A list of soil series include: Blackoar silt loam, Brussels, Clarinda, Creldon, Gatewood, Goss, Grundy, Higginsville silty, Viraton, Macedonia, Mexico, Wiota, and Chillicothe. Four pure clay mineral samples were also tested. One clay was a high cation exchange capacity montmorillonite with high exchangeable calcium. Montmorillonite clay with a low cation exchange capacity and high exchangeable sodium was also used. Other clays were Kaolinite, and Vermiculite. Soil Characterization of samples was detetrmined for clay%, silt%, organic carbon, pH (water), and cation exchange.

Six treatments were applied to all soils and minerals. Polyacrylamide was mixed with deionized water at a rate of 20 kg ha^{-1} (18 lb ac^{-1}) and 40 kg ha^{-1} (36 lb ac^{-1}). The 20 kg ha^{-1} PAM solution was mixed at 300 mg L^{-1}, while the second was mixed at 600 mg L^{-1}. Exactly 14.1 mL of each of these was applied to soil samples to match the previously mentioned application rates. 2.9 mL was added to pure samples due to the decrease in sample size. $CaCl_2$ was used to model the calcium ion availability associated with appliaction of gypsum ($CaSO_4$). The $CaCl_2$ solution was mixed with deionized water at 0.007M (0.7763 g L^{-1}), which contains the amount of Ca^{++} as gypsum at its maximum solubility in water. Calcium chloride dehydrate, minimum 99.0% was used. This solution was applied in the same fluid amounts as the two PAM solutions. Two more amendments were added by applying $CaCl_2$ with one of the PAM solutions. The final solution was an untreated check. All of the solutions were allowed to mix slowly overnight using a magnetic stirrer.

Cylinder cores were cut from PVC to pack soils into. Each piece had a height of 4.9 cm and a diameter of 5.19 cm. All soils were air dried and sieved using a 2 mm sieve. The cores had a volume of 103.6 cm^3, using a consistent bulk density of 1.25 g cm^{-3}. Solutions were applied to the cylinder samples in a two day process. PVC pipe cut into short cylinders of the same diameter were placed and taped on top of the samples for solution application. On the first day, 14.1 mL of either deionized water or the $CaCl_2$ solution is applied to each, depending on which

treatment each was to receive. The samples would sit overnight and on the second day 14.1 mL of deionized water, PAM 20 kg ha^{-1}, or PAM 40 kg ha^{-1} is applied depending on which treatment the sample was to receive. The separate days was done in order that $CaCl_2$ would be able to interact with the soil prior to application of PAM in the samples that received both. Pure samples were done exactly the same way, but with 2.9 mL of fluids. Samples were placed in a tank Using a Marriott flask, water was supplied to the tank. After allowing samples to saturate overnight, saturated mass of soil was taken and then the sample was placed on a tension table at 25 cm of tension.

A droplet former built onto a plastic tub was placed about 8.7 m above the testing location. Deionized water is placed in the plastic tub. Each droplet was 58 mg. The droplet discriminator was a system built to allow only drops that are centered to pass through to the testing location. A centered drop passed through the test tube below the discriminator arm and hit the surface of the sample. Splash from the soil surfacewas collected. Samples were placed in an oven at 105 °C and allowed to oven dry overnight. Mass of the test trays are taken the next day and the difference between before and after is the soil eroded for that sample.

Analysis of data is underway. As expected splash data indicate that the effectiveness of treatments are variable. In all cases PAM 20 kg ha^{-1} significantly reduced erosion. The benefit of increasing PAM to 40 kg ha^{-1} was only effective about 50% of the time. The benefit of adding 0.7763 g L^{-1} Ca^{++} was only effective about 50% of the time, and in some cases soil splash increased with this treatment. In less than 25% of the time, addition of Ca^{++} had a beneficial additive effect in reducing soil splash.

As yet the X-ray analysis of the soil samples has not been performed because of equipment unavailability. Thus, prediction equations relating the effect of PAM for reducing soil erodibility on these soils vs. soils properties (clay type) has yet to be developed. This will be developed in summer of 2011 to develop a guideline for users to aid in selecting the most economical and effective amount of PAM. Results of this testing will be presented at the Annual International Soil and Water Conservation Society Meetings in July 2011. This work will be submitted for peer-reviewed publication.

1. Gantzer, C.J., E.E. Alberts, and W.H. Bennett. 1985. An electronic discriminator to eliminate the problem of horizontal raindrop drift. Soil Sci. Soc. Am. J. 49:211-215.

Training:

This project assisted in the training an M.S. graduate student, and of training of one undergraduate students. The training included most aspect of research planning, preparation and implementation of the experimental work. Training will also included data preparation, data analysis, and report writing.

The project supported 1) Mr. Thomas A. Smith pursued a Masters of Science in Environmental Science graduating in May 2011, and 2) Mr. Allen T. Williams currently is pursuing a Bachelors of Science in Biological Engineering degree with a 3.89 GPA, and an expected graduation date of May 2012.

Visible Light-activated Titanium Dioxide-based Photocatalysts: Synthesis and Potential Environmental Applications

Basic Information

Title:	Visible Light-activated Titanium Dioxide-based Photocatalysts: Synthesis and Potential Environmental Applications
Project Number:	2009MO99B
Start Date:	3/1/2009
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	9
Research Category:	Water Quality
Focus Category:	Treatment, Water Quality, None
Descriptors:	None
Principal Investigators:	Baolin Deng, Baolin Deng

Publications

1. Huy Nguyen and Baolin Deng, Nitrogen-Doping of Arrays of Titanium Dioxide Nanotube by Non-Thermal Plasma Processing Technique to Improve Photoatalytic Efficiency in Visible Lights for Environmental Applications , Poster presentation on the Missouri NanoFrontiers Symposium 2010, hosted in the Washington University at St Louis.
2. Hua, B.; Veum, K.; Yang, J.; Jones, J.; Deng, B. (2010) Parallel factor analysis of fluorescence EEM spectra to identify THM precursors in lake waters", Environmental Monitoring and Assessment, 161 (1-4), pp. 71-81.

Abstract
Titanium dioxide (TiO2) has been widely used as a photocatalyst for the advanced oxidation treatment of organic contaminants and disinfection when coupled with ultraviolet (UV) radiation. Much efforts has recently focused on modifying TiO2 so it can be activated with visible light (VIS), which could result in much broader environmental applications. TiO2 doped with elements such as carbon and nitrogen (N) are found to exhibit photocatalytic effects in VIS region. The efficiency of these modified photocatalysts, however, is still low. The objective of this proposed study was to synthesize and characterize the N-doped TiO2 nanomaterials capable of significant visible light absorption and evaluate their photocatalytic reactivity under visible light radiation for the degradation of petroleum hydrocarbons, such as degradation of petroleum hydrocarbons, disinfection of treated municipal wastewater prior to final discharge to rivers and lakes, and destruction of indoor air pollutants.

TiO_2 nanotubes were prepared from titanium (Ti) foil by the anodic annodization process. This material was then treated by a non-thermal plasma processing technique in nitrogen atmosphere to achieve nitrogen doping. The results showed that TiO_2 as array of nanotubes could be nitrogen-doped with the non-thermal plasma processing technique without noticeable damage to the 1-dimensional structure. Using methylene blue (MB) as a sample organic contaminant, the doped TiO_2 nanotubes showed a clear improvement in photocatalytic efficiency, as well as effective activation with visible lights

Nature, Scope and Objective of Research:

Since the discovery of its photoactivity in 1972 (Fujishima and Honda 1972), titanium dioxide (TiO2) has been widely used as a photocatalyst for disinfection and contaminant degradation (Chen and Mao 2007). However, original TiO2 can only be activated by ultra-violet (UV) radiation due to its high energy band gap. Since less than 10% of the total solar radiation to the earth's surface is in the UV range, photocatalytic processes mediated by TiO2 require an anthropogenic UV source. Much effort has recently been devoted to modifying TiO2 to achieve activation in the visible light region (Asahi et al. 2001). Notably nitrogen (N)-doped TiO2 is found capable of absorbing visible light (Asahi and Morikawa 2007; Chen and Mao 2007). However, applications of N-doped TiO2 nanomaterials in water treatment have not been explored.

The objective of this proposed study was to synthesize and characterize the N-doped TiO2 nanomaterials capable of significant visible light absorption and evaluate their photocatalytic reactivity under visible light radiation for the degradation of petroleum hydrocarbons. This is an integral part of our long-term goal to prepare solid thin-film and nano-structured photocatalysts with a superior quantum yield and explore their environmental applications such as degradation of petroleum hydrocarbons, disinfection of treated municipal wastewater prior to final discharge to rivers and lakes, and destruction of indoor air pollutants.

This proposed study was built on mature TiO2/UV processes that have been widely used for disinfection and advanced oxidation of organic contaminants. The result from this study could extend the photocatalytic treatment processes to visible light region, avoiding the need for an UV source. Degradation of petroleum hydrocarbons was selected as the first model system for application because oil spills occur frequently; and it was envisioned that if an effective photocatalyst could be prepared that utilizes visible light radiation, application of the catalyst to the contamination sites could be a new and economical approach of contamination degradation.

Another application was for the treatment of produced water associated with gas and oil production. Dissolved aromatics hydrocarbons in the produced water include benzene, toluene, ethyl benzene and xylene (BTEX), which are potent carcinogens. Currently, produced water is mainly treated with physical treatment techniques such as filtration, gravity separation and flotation. These techniques are expensive and not able to treat the water to meet standards for reuse. Drinking water standards are even more rigid, which are 0.005, 1, 0.7, and 10 ppm for benzene, toluene, ethyl benze ne and xylene, respectively (http://www.epa.gov/safewater/contaminants/index.html#listmcl). The proposed research could potentially provide a cost-effective approach for the produced water treatment and reuse.

Synthesis and characterization of VIS-activated N-doped TiO2 photocatalysts

Two approaches were employed to prepare N-doped TiO2 photocatalyst nanomaterials in this research. The first approach was to prepare a thin solid film of N-doped TiO2 by the chemical vapor deposition method. In this approach, the N-doped TiO2 was prepared by atmospheric pressure chemical vapor deposition (APCVD) or plasma enhanced chemical vapor deposition (PECVD). Implementation of APCVD and PECVD was derived from the works of Guo et al. (2007). Precursors including TiCl4, O2 (as air) and NH3 gas react at glass substrate surface of 500-600oC for 1 minute, resulting in deposition of TiO2 and TiN on a substrate of glass. The glass with deposited layer containing TiO2 and TiN were then annealed at 500oC in nitrogen atmosphere. Conditions for sample preparation was altered including the reactant concentration and treatment time in order to obtain the best materials with the highest catalytic activity. Equipment for chemical vapor deposition and plasma enhanced chemical vapor deposition were available from Professor Hao Li's laboratories in the Department of Mechanical and Airspace Engineering of University of Missouri. The second approach was to prepare nano-structured N-doped TiO2 following the sol-gel method by hydrolysis of titanium isopropoxide (TIIP) in ammonia solution, as reported in the literature (Yu et al. 2001). TIIP is applied to ammonia solution drop-wisely. The collected sol was aged for 1 hour inside ultrasonic bath, then to be annealed at 500oC in nitrogen atmosphere. It was expected that nanorods of TiO2 will be achieved. As-prepared samples then can undergo further treatment by plasma with carrier gas of NH3. The prepared photocatalyst samples from different approaches was characterized by X-ray diffraction spectroscopy (XRD) for crystal structures and sizes - peak positions and magnitudes in XRD spectroscopy provide information on the crystal type (e.g.,

anatase or rutine) and nanoparticles size, as illustrated by Figure 1. Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) analyses was used to examine nanostructures or induced layer of TiO2 at the surface of prepared photocatalysts. Light absorption efficiency of the samples was measured by UV-VIS optical absorption analysis. Specific surface area of the prepared samples was determined by BET method using multi-point nitrogen adsorption.

Summary

TiO_2 nanotubes were prepared from titanium (Ti) foil by the anodic annodization process. This material was then treated by a non-thermal plasma processing technique in nitrogen atmosphere to achieve nitrogen doping. The results showed that TiO_2 as array of nanotubes could be nitrogen-doped with the non-thermal plasma processing technique without noticeable damage to the 1-dimensional structure. Using methylene blue (MB) as a sample organic contaminant, the doped TiO_2 nanotubes showed a clear improvement in photocatalytic efficiency, as well as effective activation with visible lights.

Literature Cited

Asahi, R. and T. Morikawa (2007). "Nitrogen complex species and its chemical nature in TiO2 for visible-light sensitized photocatalysis." Chemical Physics **339**(1-3): 57-63.
Asahi, R., T. Morikawa, et al. (2001). "Visible-light photocatalysis in nitrogen-doped titanium oxides." Science **293**(5528): 269-271.

Chen, X. and S. S. Mao (2007). "Titanium dioxide nanomaterials: Synthesis, properties, modifications and applications." Chemical Reviews **107**(7): 2891-2959.
Fujishima, A. and K. Honda (1972). Nature **37**: 238-245.

Fujishima, A. and K. Honda (1972). Nature **37**: 238-245.

Guo, Y., X. w. Zhang, et al. (2007). "Structure and properties of nitrogen-doped titanium dioxide thin films grown by atmospheric pressure chemical vapor deposition." Thin Solid Films **515**(18): 7117-7121.

Information Transfer Program Introduction

The Missouri Water Resources Research Center s objectives are: 1) to establish active research programs to aid in understanding and solving Missouri's and the Nation's water problems, 2) to provide education opportunities in research for students with an interest in water resources and related fields, and 3) to be actively dedicated to the dissemination of information through all aspects of the media.

The technology assistance program goal is to meet objective 3, dissemination of information through all aspects of the media.

The Center maintained an active information transfer program that included: 1) coordination of local seminar program, 2) publication of Water Center newsletter, 3) interaction with state and federal water agencies, 4) Director served on various national and local water related boards, organizations and committees, 5) continued cooperation with district USGS office (representative on advisory committee), 6) maintenance and expansion of comprehensive web site, 7) making available of Center's publications, 8)responding to public requests and questions, 9) meeting with advisory committee to improve information transfer activities.

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2009MO98B
Start Date:	3/1/2010
End Date:	2/28/2011
Funding Source:	104B
Congressional District:	9
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Thomas E. Clevenger

Publications

There are no publications.

The Center maintained an active information transfer program that included: 1) coordination of local seminar program, 2) publication of Water Center newsletter, 3) interaction with state and federal water agencies, 4) Director served on various national and local water related boards, organizations and committees, 5) continued cooperation with district USGS office (representative on advisory committee), 6) maintenance and expansion of comprehensive web site, 7) making available of Centers publications, 8)responding to public requests and questions, 9) meeting with advisory committee to improve information transfer activities.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	2	0	0	0	2
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	4	0	0	0	4

Notable Awards and Achievements

Funded: Univ. of MO Research Council grant has been approved in the amount of $2,792 for your project titled, Developing Guidelines for Polyacrylamide Use for Erosion Reduction. (1 Jan 2011 to 30 June 2011.)

Invited Presentation on the work at the Annual Meeting of the Soil and Water Conservation Society, July 17-20, 2011. Washington, D.C. from related work on project titled, "Developing Guidelines for Polyacrylamide use for Erosion Reduction."

Publications from Prior Years

1. 2002MO3B ("Development of Wax-Rich Grout for Borehole Sealing") - Articles in Refereed Scientific Journals - Mattingly, C.A., A.L. Thompson, and C.J. Gantzer. 2010. Influence of polyacrylamide on runoff and sediment detachment. Trans. ASABE 53: (1): 31-38.
2. 2002MO3B ("Development of Wax-Rich Grout for Borehole Sealing") - Dissertations - Mattingly, Christina A. 2004. Influence Of Raindrop Energy On Polyacrylamide Effectiveness. MS Thesis. University of Missouri-Columbia, Columbia, MO.
3. 2002MO3B ("Development of Wax-Rich Grout for Borehole Sealing") - Articles in Refereed Scientific Journals - on runoff and sediment detachment. Trans. ASABE 53: (1): 31-38. Lee, S.S., C.J. Gantzer, A.L. Thompson, S.H. Anderson, and R.A. Ketcham. 2008. Using high-resolution computed tomography analysis to characterize soil-surface seals. Soil Sci. Soc. Am. J. 72:1478-1485.
4. 2006MO63B ("Adsorption of the Isoxaflutole Degradate Diketonitrile to Aluminum and Iron Hydrous Oxides") - Articles in Refereed Scientific Journals - Wu, S.-H., K.W. Goyne, R.N. Lerch, and C.-H. Lin. 2011. Adsorption of isoxaflutole degradates to aluminum and iron hydrous oxides. J. Environ. Qual. 40: 528-537.
5. 2006MO63B ("Adsorption of the Isoxaflutole Degradate Diketonitrile to Aluminum and Iron Hydrous Oxides") - Conference Proceedings - Goyne, K.W., S.-H. Wu, R.N. Lerch, and C.-H. Lin. 2009. Adsorption of isoxaflutole degradates to hydrous metal oxides. p.141. Program and Abstracts of the 46th Annual Meeting of the Clay Minerals Society. Billings, Montana. 5-11 June 2009. Clay Minerals Society, Chantilly, VA. (Oral Invited, Session Organizer - Dr. David Laird)
6. 2006MO63B ("Adsorption of the Isoxaflutole Degradate Diketonitrile to Aluminum and Iron Hydrous Oxides") - Conference Proceedings - Wu, S.-H., K.W. Goyne, R. N. Lerch, C.-H. Lin, and S. H. Anderson. 2007. Adsorption of isoxaflutole degradates to aluminum and iron hydrous oxides. CD-ROM. ASA, CSSA, SSSA International Annual Meetings. New Orleans, LA. 4-8 Nov. 2007. ASA, CSSA, SSSA, Madison, WI. (Poster)
7. 2006MO63B ("Adsorption of the Isoxaflutole Degradate Diketonitrile to Aluminum and Iron Hydrous Oxides") - Conference Proceedings - Wu, S.-H., K.W. Goyne, R. N. Lerch, C.-H. Lin, and S. H. Anderson. 2006. Adsorption of isoxaflutole degradates to aluminum and iron hydrous oxides. CD-ROM. ASA, CSSA, SSSA International Meetings. Indianapolis, IN. 12-16 Nov. 2006. ASA, CSSA, SSSA, Madison, WI. (Poster
8. 2002MO3B ("Development of Wax-Rich Grout for Borehole Sealing") - Articles in Refereed Scientific Journals - Lee, S.S., C.J. Gantzer, A.L. Thompson, and S.H. Anderson. 2010. Polyacrylamide and gypsum amendments for erosion and runoff control on two soil series. J. Soil Water Conserv. 65:233-242.
9. 2002MO3B ("Development of Wax-Rich Grout for Borehole Sealing") - Articles in Refereed Scientific Journals - Lee, S.S., C.J. Gantzer, A.L. Thompson, S.H. Anderson, and R.A. Ketcham. 2008. Using high-resolution computed tomography analysis to characterize soil-surface seals. Soil Sci. Soc. Am. J. 72:1478-1485.
10. 2004MO34B ("The Leaching Behavior of Arsenic and Selenium from Fly Ash and Their Potential Impact on Water Quality") - Articles in Refereed Scientific Journals - Wang, Jianmin, Tian Wang, Joel G. Burken, Charles C. Chusuei, Heng Ban c,Ken Ladwig, C.P. Huang. 2008. Adsorption of arsenic(V) onto fly ash: A speciation-based approach. Science Direct. Chemosphere 72 (2008) 381 388.
11. 2004MO34B ("The Leaching Behavior of Arsenic and Selenium from Fly Ash and Their Potential Impact on Water Quality") - Articles in Refereed Scientific Journals - Wang, Jianmin, Tian Wang, Joel G. Burken, Charles C. Chusuei, Heng Ban c,Ken Ladwig, C.P. Huang. 2007. Adsorption of arsenic(V) onto fly ash: A speciation-based approach. J. Environ. Qual. 36:1784-1792.